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The relationship between backpack load, shoulder muscle strength, and shoulder pain in elementary school students

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ABSTRACT

Background: Carrying school backpacks exceeding 10% of body weight is linked to shoulder discomfort in primary school students. This study aimed to analyse whether factors such as shoulder muscle strength, carrying duration, flexibility, blood lactate levels, and age contribute to shoulder pain beyond backpack load.

Methods: This analytical observational study used a cross-sectional design involving 66 male students aged 7–10 years from SDI Maryam Surabaya, Indonesia. Standardised measurements were conducted, including shoulder pain (Wong–Baker Faces Scale), body and backpack weight (digital scale), backpack carrying duration (stopwatch), shoulder strength (dynamometer), flexibility (goniometer), and blood lactate levels (Accutrend Plus). Associations between variables were analysed using Spearman's rho correlation test.

Results: Backpack load percentage ($p = 0.020$), carrying duration (right $p = 0.010$; left $p = 0.006$), age (right $p = 0.000$; left $p = 0.001$), and shoulder muscle strength push ($p = 0.000$) and pull (left $p = 0.004$) were significantly associated with shoulder pain, while shoulder flexibility and blood lactate showed no significant relationships ($p > 0.05$).

Conclusion: Shoulder pain in primary school students was influenced by backpack load and key physiological factors, particularly shoulder muscle strength, carrying duration, and age. These findings highlighted the importance of preventive measures such as postural education and muscle-strengthening programs to reduce musculoskeletal discomfort from daily backpack use.

Keywords: backpack load, elementary students, muscle strength, shoulder flexibility, shoulder pain.

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INTRODUCTION

Musculoskeletal disorders caused by excessive backpack loads are common among elementary school students. Repeated stress from heavy backpacks can increase shoulder tension, disrupt scapular kinematics, and compress soft tissues, resulting in muscle fatigue and pain. Prolonged pressure can also cause local ischemia and increased blood lactate levels, which interfere with muscle relaxation and recovery.[1]

Epidemiological studies consistently report a high prevalence of musculoskeletal pain among school children. In India, 58.3% of students reported musculoskeletal complaints, and those who carried heavier backpacks were 3.3 times more likely to experience related disorders.[2] Similar trends were found in another study, where 50.9% of boys and 63.9% of girls experienced musculoskeletal pain, with higher rates in private schools.[3] In Indonesia, 42.4% of elementary school students aged 6–11 years reported shoulder pain related to backpack weight, with an average backpack weight of 3.1–3.5 kg. These findings highlight that musculoskeletal strain related to backpacks remains a persistent public health issue.[4]

Sedentary behavior in the digital age exacerbates this problem, as limited physical activity weakens postural muscles and shoulder stabilizers, making children more prone to pain even when backpack loads are kept below the recommended limit of 10% of body weight. The American Occupational Therapy Association (AOTA) recommends keeping the load below this limit to reduce the risk of postural deformities such as kyphosis, scoliosis, and lordosis.[5] However, biomechanical evidence shows that prolonged asymmetrical loads can alter scapular position, increase upper trapezius muscle activation, and reduce blood flow, contributing to cumulative fatigue and shoulder discomfort.[6]

Interestingly, not all students who carried heavier backpacks experienced shoulder pain, while some who carried lighter loads still reported discomfort. This inconsistency suggests that factors beyond mechanical load influence pain perception and muscle response. Variables such as shoulder muscle strength, flexibility, duration of backpack carrying, and biochemical stress indicators, particularly blood lactate, may contribute to the onset of pain, but these factors remain underexplored in children.[7]

This study aimed to analyze the relationships between backpack load, duration of use, shoulder muscle strength and flexibility, blood lactate levels, and age with shoulder pain in male students aged 7–10 years. By integrating biomechanical and physiological perspectives, the study sought to provide a clearer understanding of early musculoskeletal risk factors in school-aged children.

METHODS

This study used an analytical observational design with a cross-sectional approach and was conducted at SDI Maryam, Surabaya, Indonesia, from February 4 to 6, 2025. The purpose of this study was to analyze the relationship between backpack load, duration of backpack use, shoulder muscle strength and flexibility, blood lactate levels, age, and shoulder muscle pain in elementary school students. A total of 66 male students aged 7–10 years were recruited using purposive sampling. Written consent was obtained from parents or guardians, and confidentiality was ensured through coded identification. Students with a history of acute injury or musculoskeletal disorders affecting the shoulder were excluded. Ethical approval was granted by the Health Research Ethics Committee, Faculty of Medicine, Airlangga University (Approval Number: 216/EC/KEPK/FKUA/2024).

Before data collection, the objectives and procedures of the study were explained to students and parents. All assessments were conducted by trained researchers under medical supervision, with the assistance of classroom teachers. Shoulder pain intensity was measured using the Wong–Baker Faces Pain Rating Scale (0–10).[8] Body weight and backpack weight were measured using digital scales (Tanita BC-532), while the duration of carrying the backpack from home to school was recorded using a stopwatch.[9,10] Shoulder muscle strength (push and pull) was evaluated using a hand dynamometer, while shoulder flexibility was measured using a goniometer.[11,12] Blood lactate levels were obtained through finger capillary sampling using an Accutrend Plus device (Roche Diagnostics).[13]

Data analysis was performed using SPSS version 25.0. The *Kolmogorov–Smirnov* test was used to assess data normality. *Pearson's* correlation analysis was applied to normally distributed variables, while *Spearman's* rho was used for non-normal data. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 66 male students aged 7–10 years from SDI Maryam Surabaya participated in this study. **Table 1** shows their descriptive characteristics, including age, anthropometric data, and physiological measurements. The average age was 8.37 ± 1.06 years, with an average weight of 29.17 ± 9.87 kg and height of 127.56 ± 8.26 cm. The average backpack weight was 3.18 ± 0.63 kg (11.84 ± 3.72% of body weight), and the average carrying duration was 1.96 ± 1.24 minutes. The average shoulder muscle strength was 1.69 ± 1.07 kg (pull) and 1.46 ± 0.90 kg (push). The shoulder flexibility angle was similar on the right (161.06 ± 10.61°) and left (160.98 ± 10.60°) sides. The average blood lactate concentration was 3.46 ± 2.24 mmol/L, and the average pain score was 2.68 ± 2.52 (right) and 2.50 ± 2.36 (left).

Table 2 shows the results of Spearman's rho correlation analysis. The percentage of backpack load was significantly correlated with right shoulder pain (p = 0.020) but not with left shoulder pain (p = 0.176). The duration of backpack carrying was significantly associated with right shoulder pain (p = 0.010) and left shoulder pain (p = 0.006). Age was negatively correlated with shoulder pain on both sides (right p = 0.000; left p = 0.001), indicating that older students experienced less discomfort. Shoulder muscle strength (pull) was significantly correlated with left shoulder pain (p = 0.004), while push strength was significantly correlated with pain on both

Table 1. Characteristics of study participants

Variable	Min	Max	Mean ± SD
Age (years)	7	10	8.37 ± 1.06
Height (cm)	110.40	143.50	127.56 ± 8.26
Body weight (kg)	16.60	61.20	29.17 ± 9.87
Backpack weight (kg)	1.40	4.70	3.18 ± 0.63
Backpack load (%)	4.25%	19.88%	11.84 ± 3.72
Carrying duration (minutes)	1.01	7.01	1.96 ± 1.24
Shoulder muscle strength (pull) (kg)	0.00	5.00	1.69 ± 1.07
Shoulder muscle strength (push) (kg)	0.50	4.00	1.46 ± 0.90
Right shoulder flexibility (°)	135	180	161.06 ± 10.61
Left shoulder flexibility (°)	130	180	160.98 ± 10.60
Blood lactate (mmol/L)	1.40	17.80	3.46 ± 2.24
Right shoulder pain (VAS)	0	9	2.68 ± 2.52
Left shoulder pain (VAS)	0	9	2.500 ± 2.36

Table 2. Results of the *Spearman's rho* correlation test between characteristic variables and shoulder pain

Variable	Right (p-value)	Left (p-value)
Backpack load (%)	0.020	0.176
Carrying duration (minutes)	0.010	0.006
Age (years)	<0.001	0.001
Shoulder muscle strength (pull)	0.033	0.004
Shoulder muscle strength (push)	0.000	0.000
Shoulder flexibility (°)	0.867	0.486
Blood lactate levels (mmol/L)	0.709	0.158

mmol/L, millimoles per litter

sides ($p = 0.000$). Shoulder flexibility did not show a significant relationship with shoulder pain ($p > 0.05$), and blood lactate levels were also not significantly correlated with right shoulder pain ($p = 0.709$) or left shoulder pain ($p = 0.158$).

Figure 1 illustrates the relationship between backpack load percentage and shoulder pain. Most students reported mild pain (score 0–4), although a few reported high levels of pain (scores 5–9) with no clear trend indicating that heavier loads consistently increased pain. This suggests that pain is influenced by additional factors such as inadequate muscle strength or duration of carrying.[14] **Figure 2** shows that shoulder pain was more frequently reported during shorter carrying durations (1–2 minutes), although some students continued to report mild to moderate pain with longer durations. This indicates that pain is influenced not only by the duration of backpack carrying but also by load, muscle adaptation, and strength.[15]

Figure 3 shows that shoulder pain generally decreases with age, although some older students still reported pain. This pattern suggests that older students likely have better posture and muscle strength, consistent with previous findings.[16] **Figure 4a** and **4b** illustrate the distribution of shoulder pain based on muscle strength during pulling and pushing movements. Students with lower muscle strength experienced more pain, while stronger students generally reported less discomfort. These findings suggest that shoulder muscle strength plays an important role in supporting backpack weight and reducing pain.[17]

Figure 5 illustrates the relationship between shoulder flexibility and pain. Students with lower flexibility tended to report higher levels of pain, although some students with good flexibility still experienced discomfort, indicating that flexibility alone does not determine pain.[18] **Figure 6** shows the relationship between lactate levels and shoulder pain. Most of the data is concentrated below lactate levels of 4–5 mmol/L with significantly varying pain scores, and no clear pattern is observed. This suggests that lactate levels are not consistently associated with shoulder pain on either side.[19]

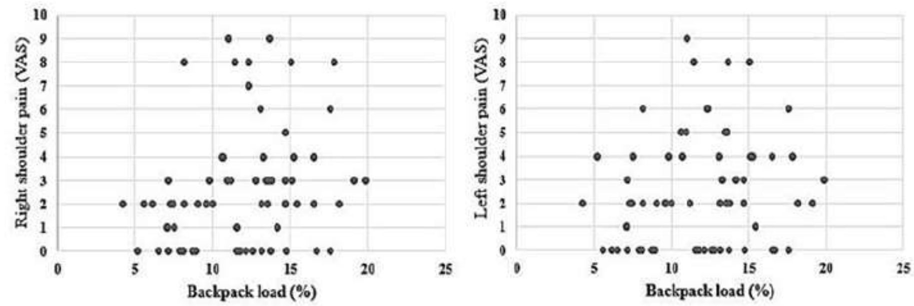

Figure 1. Backpack load with right and left shoulder pain

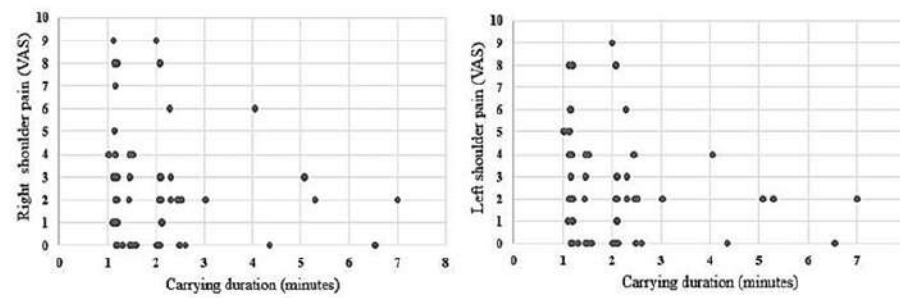

Figure 2. Carrying duration with right and left shoulder pain

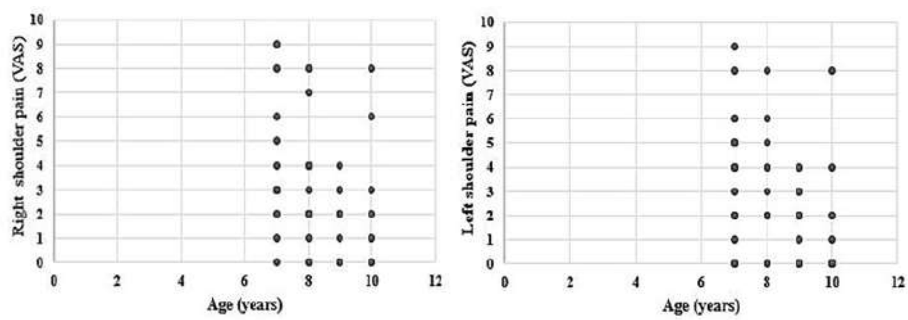

Figure 3. Age with right and left shoulder pain

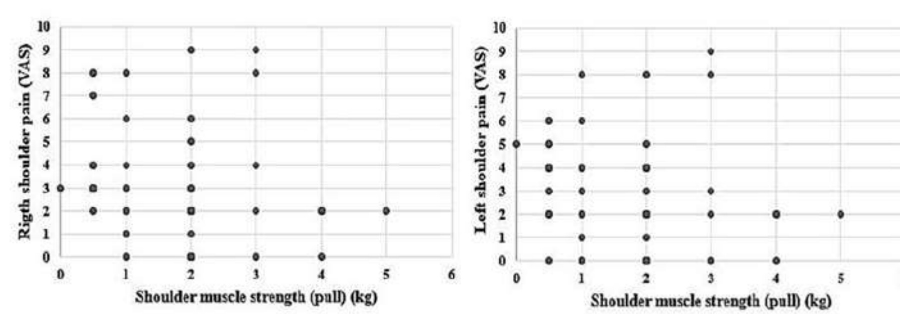

Figure 4a. Muscle strength pull with right and left shoulder pain

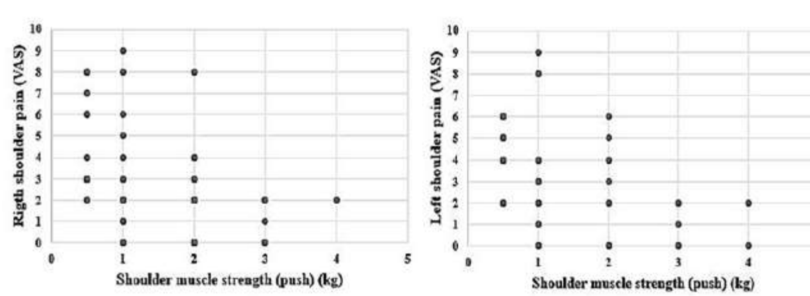

Figure 4b. Muscle strength push with right and left shoulder pain

DISCUSSION

Shoulder muscle pain in school-aged children due to backpack use is a multifactorial problem involving mechanical, physiological, and neuromuscular factors. This study found that backpack weight, duration of use, age, and shoulder muscle strength were significant determinants of shoulder pain, while shoulder flexibility and blood lactate levels showed no significant relationship. These findings highlight that shoulder discomfort in children is not only influenced by external load but also by the combined effects of biomechanical and physiological factors.[1]

A significant relationship between backpack load and right shoulder pain supports the theory of excessive mechanical load, which states that excessive compression and shear forces on the trapezius, deltoid, and scapular stabilizer muscles can cause microtrauma and local ischemia, resulting in pain.[9,15] More severe pain on the right side, despite the symmetrical backpack design, likely reflects habitual load distribution and right arm dominance.[16] This unilateral stress can alter scapular position, contributing to scapular dysfunction and increased muscle tension. Further reduction in local perfusion limits oxygen delivery, accelerating fatigue and pain. Although the 10% body weight guideline is often recommended, it does not account for variations in muscle condition, postural control, or endurance.[5] Some children in this study carried loads exceeding 10% of body weight without discomfort, indicating adequate adaptation and neuromuscular efficiency, while others reported pain with lighter loads, suggesting underlying factors such as muscle weakness or limited endurance.[8,15]

Prolonged carrying times showed a significant positive correlation with shoulder muscle pain, consistent with evidence that prolonged static loads increase mechanical fatigue in the shoulder and neck muscles.[17] Interestingly, older students reported fewer pain complaints despite carrying their backpacks for longer periods, possibly due to progressive muscle adaptation, in which repeated submaximal loads increase muscle strength, endurance, and the oxidative capacity of type I muscle fibers.[20] This adaptation reduces fatigue sensitivity and decreases perceived pain, whereas younger children (7–8 years) have less mature musculoskeletal structures and lower oxidative enzyme activity, making them more susceptible to fatigue and early discomfort under the same mechanical load.[21]

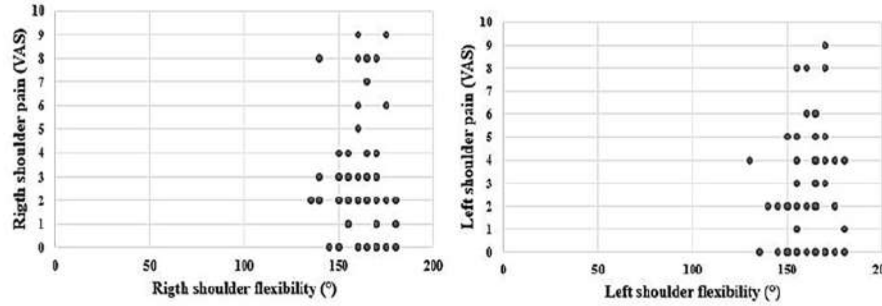

Figure 5. Shoulder flexibility with shoulder muscle pain on the right and left

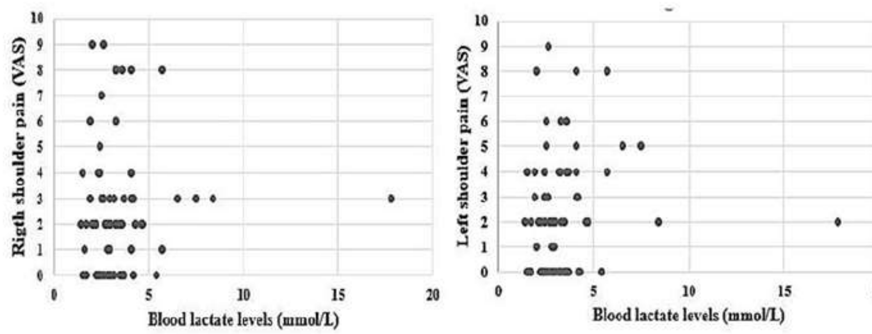

Figure 6. Lactate levels with shoulder muscle pain (right and left)

The negative correlation between shoulder muscle strength and pain indicates that greater muscle capacity can help reduce mechanical stress on the joints. Stronger shoulder-lifting muscles (trapezius, levator scapulae) and stabilizing muscles (serratus anterior, rhomboids) maintain proper scapular position and minimize compressive stress on the glenohumeral joint when carrying a backpack. When these muscles are weak, the scapula tends to rotate downward or protract, increasing tension on the upper trapezius and deltoid, which contributes to pain. The results of the study show that students with weaker shoulder strength experience more pain even when carrying similar backpack loads. This highlights the importance of shoulder and core strengthening programs in school-based ergonomics, as targeted exercises for scapular stabilizer muscles can increase load tolerance, improve posture, and reduce musculoskeletal complaints in children.[9,17]

No significant relationship was found between blood lactate levels and shoulder pain. This suggests that carrying a backpack is a low-intensity static activity that produces minimal metabolic demand, keeping lactate levels well below the 4–5 mmol/L threshold associated with muscle acidosis.[22,23] Children also clear lactate more efficiently than adults due to higher oxidative capacity and faster capillary flow, allowing for rapid recovery after low-intensity activity.[24] Furthermore, evidence that vibration massage accelerates post-exercise lactate clearance further supports the interpretation that pain in this context is triggered more by mechanical stress than metabolic accumulation.[25] Furthermore, skeletal troponin I has been identified as a sensitive biomarker of muscle damage after eccentric loading, suggesting that biochemical stress markers such as lactate and troponin may reflect muscle stress from repeated submaximal loading such as daily backpack use.[26]

The clinical relevance of this study lies in its contribution to the early prevention of musculoskeletal problems in children. Teachers and parents need to be educated to monitor the weight of backpacks, the duration of backpack use, and children's posture. Strengthening exercises and posture correction, especially for the scapular stabilizer muscles and upper body muscles, can help reduce pain and prevent postural deformities. Ergonomic strategies, including lighter backpack designs and regular breaks, can further reduce shoulder strain during school activities.

This study was limited by the inclusion of only boys aged 7–10 years, which may reduce the generalizability of the findings to female students or other age groups. The cross-sectional design also precludes causal interpretation, and the absence of electromyography (EMG) or imaging assessments restricts the detailed evaluation of scapular muscle activity. Future studies should adopt a longitudinal design, incorporate EMG and 3D motion analysis to assess scapular kinematics under load, and investigate biochemical markers such as cardiac troponin I, creatine kinase, and myoglobin to detect early signs of subclinical muscle injury.

CONCLUSION

This study showed that shoulder pain in primary school students was significantly influenced by backpack load, carrying duration, shoulder muscle strength, and age. Heavy backpacks and prolonged carrying increased biomechanical stress and muscle fatigue, whereas stronger shoulder muscles reduced pain risk. Younger children were more vulnerable due to limited neuromuscular development. These findings highlight the need for early prevention through ergonomic education, appropriate backpack design, and routine strengthening exercises. Collaboration between physiotherapists and educators is essential to monitor backpack load and promote shoulder stability. Future research should investigate the long-term effects of backpack use and evaluate targeted interventions to reduce shoulder pain in children.

ETHICAL CONSIDERATIONS

Ethical approval was granted by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Airlangga (Approval No. 216/EC/KEPK/FKUA/2024). Written informed consent was obtained from all participants and their parents or guardians. Participant confidentiality and anonymity were maintained throughout the study.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to the research, authorship, or publication of this article.

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AUTHOR CONTRIBUTIONS

HR developed the study concept and design, defined the intellectual content, and served as the guarantor of the work. GMS conducted the literature review and performed the clinical and experimental procedures. MFQ carried out data acquisition, data analysis, and statistical processing. EACP prepared, edited, and reviewed the manuscript. All authors read and approved the final manuscript and accept responsibility for all aspects of the work.

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